

Comparison of two simple techniques to extract path precipitable water from AVIRIS radiance data: CIBR and "Narrow/Wide band ratio" - Sensitivity analysis and application to AVIRIS data

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Atmospheric water vapor is a key driver to global circulation. As such, it is of interest in studies involving weather, climate modeling, and hydrologic cycles. In addition, water vapor band and continuum absorptions provide substantial obstacles to remote sensing of the Earth's surface in the 400-2500 nm region. Accurate determination of the abundance and spatial variability of water vapor is therefore important for the understanding of fundamental hydrologic questions and when compensating for atmospheric effects in the determination of surface reflectance.

Two simple techniques to retrieve path precipitable water from AVIRIS high spectral resolution radiance data, using the 940 nm water absorption band, are compared. The first technique, named CIBR (Continuum Interpolated Band Ratio, Green et al., 1990), retrieves total column abundance using a ratio between the radiance at the wavelength of maximum absorption and the Interpolated continuum from both sides of that absorption. The second one ("N/W", Frouin and Middleton, 1990) is based on the ratio of a "narrow band" located at the maximum absorption, consisting here of an average of three AVIRIS channels between 935 and 955 nm, to a "wide band" average of bands located in the symmetrical portion of the water absorption band and centered on the narrow band, here seven AVIRIS channels between 920 and 970 nm. In both cases, the ratio is then related to the amount of precipitable water through a calibration curve obtained by running LOWTRAN 7 for flight conditions, an assumed background reflectance of 0.25 and increasing amounts of water ranging from 0 to 200% of the standard moisture density profile resident in the code. Total radiances predicted by LOWTRAN 7 are then convolved to AVIRIS spectral resolution, CIBR or N/W is performed for each amount of water, and a file that relates the CIBR or N/W values to the amount of water is created. Previous sensitivity analysis (Carrere et al., 1990, Conel and Carrere, 1990) showed that CIBR was sensitive to background reflectance, visibility, and aerosol model. On the other hand, the N/W ratio has been shown by Frouin and Middleton (1990) to be rather insensitive to background reflectance and visibility changes when applied to field radiometer data. It is also less sensitive to changes in the amount of water due to the fact that it does not measure the full depth of the absorption band. The 940 nm water band was selected because it is not very saturated, and is thus more sensitive to any change in the amount of water. Since the shape and depth of the atmospheric water bands are influenced not only by the water present but also by surface (background) reflectance, atmospheric scattering and instrument calibration, and we are assuming a constant background reflectance and have sometimes little knowledge about the atmospheric parameters such as visibility and type of aerosols when building the calibration curve, a sensitivity analysis was performed using the radiative transfer code LOWTRAN 7 to determine which one of these two approaches will provide a better estimate. This analysis was based on a normalized difference between the reference calibration curve (constant background reflectance, 25 km visibility, rural aerosols, zero meter target elevation, April 18, 11:05 a.m.) and the new calibration curve built by varying one of

the parameters. Sensitivity to background reflectance (vegetation, gypsum, iron oxides versus an assumed constant background reflectance of 25%), visibility variations, types of aerosols, shift in AVIRIS in-flight band positions and bandwidth from the laboratory calibration as well as the effect of off-nadir viewing (15°) at the edge of the flight line were analyzed. In every case, the N/W approach was less sensitive to these effects than the CIBR (average accuracy of 1%). It was, however, more sensitive to scattering due to off-nadir looking at the edge of the flight line. Both techniques were almost equally sensitive (2 to 3%) to shift in band position and change in bandwidth greater than 0.1 nm. This sensitivity analysis also pointed out problems in the way LOWTRAN 7 models visibility, scattering, and aerosols.

Both techniques were then applied to AVIRIS radiance data. When simultaneous atmospheric measurements were available, an independent estimate of water vapor from Reagan sunphotometer measurements (see Bruegge et al., 1990, for method and validation) was provided and compared to the AVIRIS estimate.

Two cases are presented:

(1) Salton Sea, California, where simultaneous atmospheric measurements were available, the environment very humid, and a variable background is present.

(2) Gypsum Plain (Texas), where nothing was known about atmospheric parameters and the background reflectance is composed of gypsum, iron oxides and carbonates.

Results show that:

(1) at Salton Sea, as predicted by the sensitivity analysis, the N/W approach retrieves an amount of water close to the amount retrieved in situ by the Reagan sunphotometer. The amount retrieved using CIBR is underestimated by up to 4 mm (14%). An analysis of the instrument noise needs to be added to take into account random errors in the recovery. This analysis is under way. Both techniques recovered more water over the green fields than over bare soils. If we calculate the difference between the amount of water retrieved by the two techniques and compare it to an NDVI, we confirm that the maximum difference between the two techniques occurs over green fields, as expected from the sensitivity analysis. The only problem is that this difference is in the wrong direction. The sensitivity analysis predicts that we should recover more water with the CIBR than with the N/W approach over the green fields whereas the reverse is actually what we observe on the images. A possible explanation is that the excess water retrieved over the fields comes from evapotranspiration and not water introduced by liquid water absorption in the plants. This has to be confirmed by acquiring sunphotometer measurements in a green field simultaneously with an AVIRIS measurement or by some measurement independent of the surface water.

(2) at Gypsum Plain, results show a very narrow range and a very low amount of water for that day. One can notice similar patterns in both maps but with a slightly wider range of water for the CIBR. This is consistent with the sensitivity analysis which predicted a similar behaviour for both techniques. The difference in amount retrieved by the two techniques shows that here, the CIBR retrieves more water than the N/W. No clear relationship could be established with outcrops of bare gypsum based on a map established using the 1750 nm diagnostic absorption feature. Higher water amounts on the South East side of the flight line can be related to backscattering, which might be an indication that the visibility of 30 km used to build the calibration file was too high.

In conclusion, comparison between sensitivity analysis and image data show that we are on the right track to accurately retrieve total column abundance of water vapor but some problems still remain. N/W proved to be a more accurate approach, although less

sensitive to changes in water amount. The approach will be validated by acquiring simultaneous measurements of water in a green field and in bare soil area.

Future plans include:

- (1) Running the same sensitivity analysis for the 1130 nm water band, which is more saturated than the 940 nm one but less affected by aerosols by comparing the results; it would be interesting to do the same for the 825nm water band which is the less saturated one but it is very weak at AVIRIS resolution and might require spatial averaging to increase the signal-to-noise;
- (2) Running the same sensitivity analysis using MODTRAN instead of LOWTRAN 7, the modelling of the water absorptions in MODTRAN being supposedly more accurate;
- (3) Including the instrument noise as random source of error;
- (4) Comparing the results from these two fast and simple techniques to more sophisticated but time-consuming approaches such as least-square-fitting.

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